Liard Highway

Potential Effects on Moose and Other Wildlife

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N.W.T. Wildlife Service
Government of the Northwest Territories

AN ASSESSMENT OF POTENTIAL EFFECTS OF THE LIARD HIGHWAY ON MOOSE AND OTHER WILDLIFE POPULATIONS IN THE LOWER LIARD VALLEY

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by

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ABSTRACT

This study was undertaken for the Northwest Territories Wildlife Service in order:

(1) to collect baseline information on moose populations in the lower Liard River Valley, and
(2) to evaluate the effect of the Liard Highway, currently under construction, on moose and other wildlife populations.

The estimated number of moose in the 5512 km^2 study area in January-February of 1979 was 720 ± 141. Densities ranged from $0.024 \pm .0111/km^2$ over most of the study area to $0.75 \pm .227/km^2$ on the Liard floodplain in the upper part of the study area. The mean density was $0.131 \pm .0255$ moose/km^2. Calves comprised 13.3% of 113 moose classified between January and March, a fairly low level of recruitment. Fires are controlled throughout the Liard Valley, so that little new moose habitat is being created. Woodland caribou numbers were too low to estimate. At least one wolf pack occupied the area. Black bears used the islands in the Liard River for denning.

Several potential impacts are associated with activity during construction of the highway and traffic after its completion. The major impact of the highway may come from the access it provides. Increased hunter access may increase harvest and, because of low moose densities, low recruitment, and aging habitat, may cause a decline in moose numbers. If logging becomes established or the incidence of fires increases, moose habitat could improve and populations could increase. The islands and alluvial flats of the Liard are important areas for wildlife. Recommendations are made to minimize the impact of highway construction and the access it provides, and to maintain and improve habitat quality.

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INTRODUCTION

This study was initiated to assess the effect of the Liard Highway and its associated access on moose and other wildlife populations of the Liard River Valley, Northwest Territories. The Liard Highway will link the Mackenzie Highway in the Northwest Territories with the Alaska Highway in British Columbia. The first 22 km of the 254 km Northwest Territories portion of the highway were constructed in 1979 (Decker and Mackenzie 1979). Construction then ceased and resumed in 1978. The highway should be completed in 1981.

The Liard Valley supports populations of moose (Alces alces andersoni), woodland caribou (Rangifer tarandus caribou) black bear (Ursus americanus), marten (Martes americana), beaver (Castor canadensis), and other wildlife species hunted and trapped by the residents of Fort Simpson, Nahanni Butte and Fort Liard. In 1978 the Northwest Territories Wildlife Service undertook a preliminary survey of the area to determine winter distribution of moose (Decker and Mackenzie 1979). In 1979 this work continued. The objectives of our study were:

(1) to establish baseline information on moose population size, recruitment, and distribution in the lower Liard Valley from Nahanni Butte to Fort Simpson, and
(2) to assess potential effects of the highway, its construction, and the access it provides, on moose and other wildlife populations of the area.

STUDY AREA

The study area lies in the valley of the lower Liard River between Nahanni Butte and Fort Simpson, Northwest Territories (Fig. 1). Boundaries of the 5512 km^2 area lie roughly 20 km on each side of the Liard Highway south to km 120. The climate is subarctic - cold and dry. At Fort Simpson, mean annual precipitation is 35 cm including 135 cm of snow. (Land Use Information series map, Department of the Environment, 1976 edition.) Most of the area is flat or gently sloping. Elevation of the study area ranges from 120 to 460 m; elevations of the surveyed quadrats ranged from 150 to 380 m.

Vegetation is typical of the boreal forest as described by Rowe (1972). White spruce (Picea glauca), balsam poplar (Populus balsamifera), willows, especially Salix interior, and alders (Alnus incana), grow on the alluvial flats. On higher ground, tree species include black spruce (Picea mariana), white spruce, white birch (Betula papyrifera), trembling aspen (Populus tremuloides), and balsam poplar (Hirvonen 1968). In 1942, most of the study area burned (Hirvonen 1968). More recently, most fires have been controlled. In the past 13 years, only 2% of the study area has burned (Northwest Lands and Forest Service map) in three fires which occurred in 1966 and 1967 (Fig. 1).

METHODS

Survey Design

For the aerial moose census we used a stratified quadrat design. The study area was divided into two strata and 1378 4-km^2 quadrats. The initial quadrat in each stratum was randomly selected. The rest were systematically spaced. The 1325-quadrat Stratum 1 was given 6.3% coverage; 53-quadrat Stratum 2 was given 17.0% coverage. The high coverage stratum included areas of high moose density delineated by Decker and Mackenzie (1979) and an 84 km^2 area that burned in 1967. Observer bias was estimated using Cook and Jacobson's (1978) model.

Aerial Survey

The first 34 of the 93 quadrat were surveyed with a Piper PA-18 Supercub in January 1979 (Table 1). This aircraft could not be used below -30°C. The cold weather in February forced us to finish the survey with a Cessna 185. Total flying time was 70 hours. In the Cessna 185, as in the Supercub, the observer sat directly behind the pilot. Quadrats were located using 1:50,000 topographic maps. Their boundaries were defined by timing each 2 km side at 130 km/hr (80 mph) for 56 seconds using a stopwatch. The quadrat was then searched using three parallel lines of overlapping left hand circles at approximately 150m agl (above ground level) and 130 km/hr. Search time ranged from 10 to 52 minutes with a mean time of 26.4 min/quadrat. The rate of searching time (6.6 min/km^2) was similar to that of Evans, Troyer and Lensink (1966) in their quadrat census of moose in Alaska (6.0 min/km^2) and longer than that of Peek, Urich and Mackie (1976) in Minnesota (3.8 min/km^2). Moose were classified as adults or calves. We estimated the per cent ground cover of the following vegetation types: spruce, deciduous, muskeg, riparian and burn.

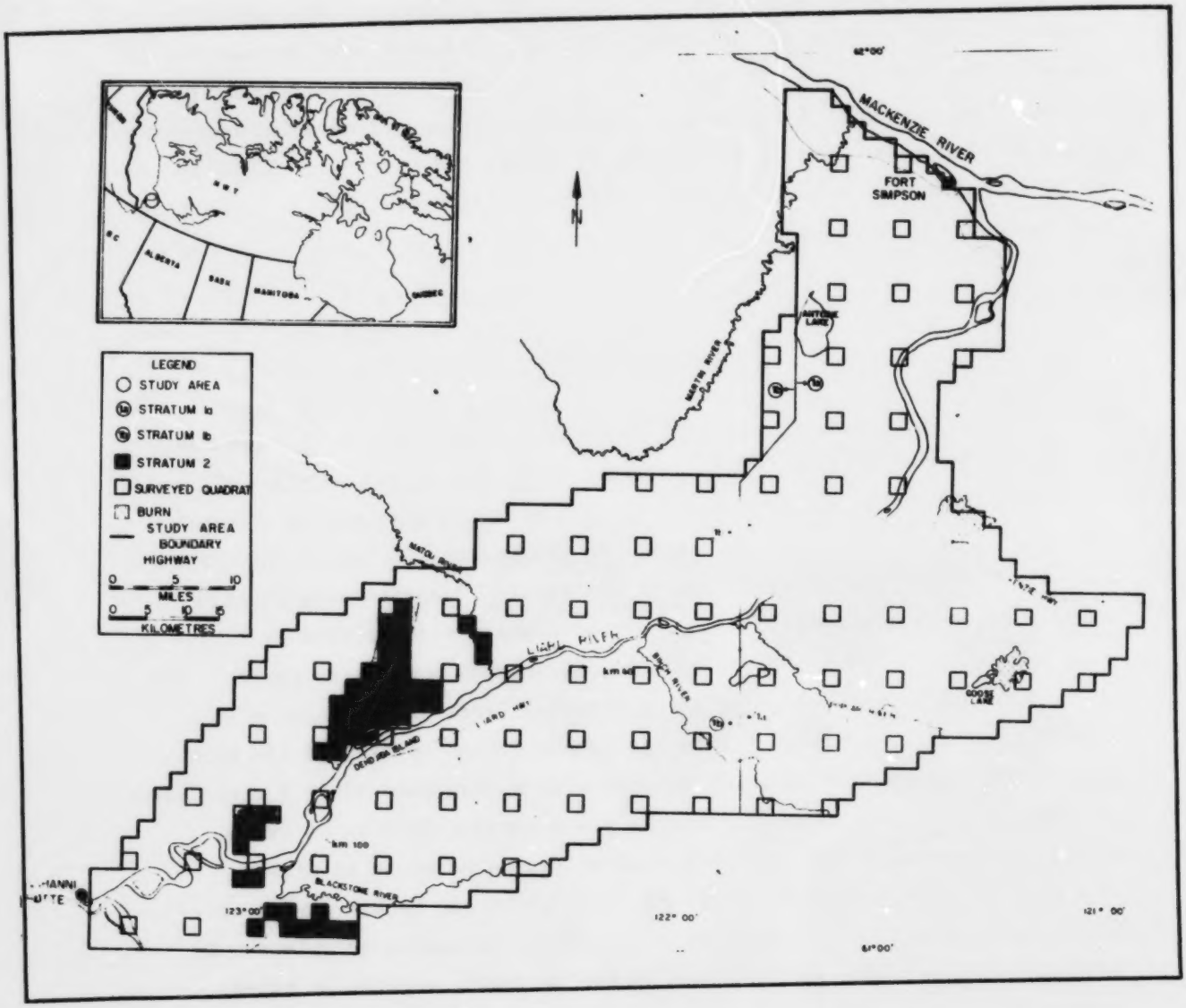

Figure 1. Location of study area, strata and quadrats.

Table 1. Timing and methods of the aerial survey of moose in the Liard River Valley.

Dates	Aircraft	Observers	Hours	Quadrats	Time per quadrat (min)	
					Mean	Standard deviation
1979						
Jan. 24-29	Piper PA-18	1	25.6	34	25.4	7.084
Feb. 16-20	Cessna 185	1	29.7	40	27.3	8.948
Feb. 21-24	Cessna 185	2	14.4	19	26.1	7.490

Observer bias was estimated on the last 19 quadrats. On nine quadrats, a second observer (Observer 2) sat directly behind Observer 1 and the pilot on the left side of the aircraft. The front observer recorded moose sightings as usual and reported each to the rear observer. The rear observer recorded any moose missed by the front observer. On the remaining 10 quadrats, the two observers switched roles. Observer 2 took the front position; Observer 1 recorded any moose Observer 2 missed.

Analysis

Bias Estimate

The probability (p), of a group of moose being seen during the aerial survey, is $p=1-(1-a_1)(1-a_2)$ where a_i = the probability that a group is seen by Observer i (Cook and Jacobson 1978). The maximum likelihood estimates of a_1 and a_2 are:

$$\hat{a}_1 = \frac{x_{11}x_{22}-x_{12}x_{21}}{x_{11}x_{22}+x_{22}x_{21}}$$

and

$$\hat{a}_2 = \frac{x_{11}x_{22}-x_{12}x_{21}}{x_{11}x_{22}+x_{11}x_{12}}$$

where x_{ij} = the number of groups seen by Observer i in the j^{th} half of the 19 quadrats surveyed.

Population Estimate

Moose density in Stratum 1 was several times higher in the western, upper part of the stratum than in the eastern, lower section. Consequently Stratum 1 was post-stratified (Cochrane 1977) into two strata, 1a and 1b, for analysis. The population total for each of the three strata, $\hat{Y}_h$, was estimated by $Y_h=N\bar{y}$ where N = number of quadrats in the stratum and $\bar{Y}$ = mean number of moose per sampled quadrat.

The variance of Y_h was estimated by Var $\hat{Y}_h = \frac{N(N-n)\ s^2}{n}$ where n = number of sampled quadrats and s^2 = sample variance. The estimated population total for the study area, $\hat{Y}$, is the sum of the three strata estimates (ΣY_h). Its variance, Var Y, is the sum of the strata variances (ΣVar Y_h). The estimated number of moose per km^2, $\bar{m}$, was $\bar{m} = \frac{\hat{Y}}{k}$ where k = number of km^2 in the study area. The variance of $\bar{m}$, Var $\bar{m}$, is Var $\bar{m} = \frac{\text{Var } \hat{Y}}{k^2}$.

Other Surveys

The N.W.T. Wildlife Service conducted three aerial transect surveys during late February and March 1979, in the area between the Liard and Kakisa Rivers. These surveys were part of a larger study to estimate moose and woodland caribou numbers in the Fort Smith region. The Liard River block of these surveys partially overlapped the area covered by our survey. Two contiguous blocks lay immediately east and west of the Redknife Hills and the 120th meridian of longitude. The northwest corner of these blocks was 40 km southeast of our study area. Block size in the three surveys ranged from 2360 km^2 to 2647 km^2; coverage ranged from 4.0 to 7.6%. The surveys were flown in a Cessna 185 aircraft at 160 km/hr. and 150m agl. One observer sat behind the pilot and two observers sat on the right side of the aircraft. Observer bias was estimated in the same manner as in our study.

RESULTS

Moose

Numbers, Recruitment, Group Size

The estimated bias based on Cook and Jacobson's (1978) model was 0. Observers in the front seat saw 24 moose in 16 groups. The rear observer detected no groups missed by the front observers. (By contrast, using the same observers and the same model, observations from the Redknife Hills study area indicated that the individual observers saw 62% and 65% of the moose (a_1 and a_2). Together they saw an estimated 87% of the moose on transect (p)).

The estimated number of moose in the study area ($\pm$ one standard error) is 740 ± 141: 30 ± 22.2 in Stratum 1a, 610 ± 128 in Stratum 1b, and 80 ± 53 in Stratum 2 (Table 2). This is equivalent to an overall density of $0.131 \pm .0255$ moose/km^2, or $0.014 \pm .0091$, $0.21 \pm .045$, and $0.36 \pm .249$ moose/km^2 in Strata 1a, 1b, and 2 respectively.

Of 113 moose classified, 13.3% were calves (Table 3). This estimate is close to that for the Redknife Hills study area where calves represented 12.0% of the 25 classified moose. Of 12 cows with calves on the Liard study area, 25% had twins.

The mean group size of $1.55 \pm .114$(n=73) did not differ between 39 groups seen on quadrats ($\bar{y} = 1.41 \pm .108$) and 34 groups seen off quadrats ($\bar{y} = 1.71 \pm .209$, $t=1.255, p > .20$). Tendency to aggregate depended on age-sex class. All 12 cow-calf groups were alone. In contrast, 9 out of 10 antlered bulls (yearlings or 2 year olds) were accompanied by other moose, seven by other young bulls.

Table 2. Results of the 1979 aerial moose census in the Liard River Valley.

Stratum	Number of quadrats sampled	Total quadrats	Per cent coverage	Moose seen	Population estimate	Variance of population estimate	Area (km^2)	Moose/ km^2
1a	37	607	6.10	2	32.8	491.4	2428	0.014
1b	47	718	6.55	40	611.1	16480.6	2872	0.213
2	9	53	16.98	13	76.6	2792.6	212	0.361
Total	93	1378	6.75	55	720.4	19764.7	5512	0.131

Table 3. Estimation of per cent calves in the Liard River moose population.

	Total	Adults	Calves	Per cent calves
Quadrats survey	51	44	7	13.7
Off quadrats	34	30	4	11.8
Transect survey[1]	28	24	4	14.3
Total	113	98	15	13.3

[1] N.W.T. Wildlife Service Survey, February, March 1979.

Distribution

The distribution of moose was determined in relation to four habitat types: the Liard River floodplain, recent burns, older burns, and forest-muskeg. The area up to 1 km from the Liard River above km 60 of the Liard Highway (between the confluences of the Birch and Matou Rivers with the Liard) is referred to as the Liard floodplain. Below km 60 the river narrows and drops more rapidly, leaving high banks and little recent floodplain. This arbitrary definition of the floodplain probably corresponds fairly closely to the actual floodplain except in the upper reaches of the Liard where the floodplain may considerably exceed 1 km.

The habitat type referred to as recent burns is the area burned by three fires in 1966 and 1967 (Figs. 1 and 2). These areas have fairly dense shrub cover of willows and aspens. Older burns refers to areas recognized as burns during the aerial survey, but not recorded on the Northwest Lands and Forest Service map of fires since 1966. The rest of the study area consists mainly of boreal mixed wood resulting from succession on the 1942 burn, and black spruce-sphagnum muskeg. It is referred to as forest-muskeg.

The number of moose per quadrat differed significantly among these habitat types (Table 4). Planned comparisons revealed that the floodplain and recent burns supported a much higher density of moose than forest-muskeg (Table 4 and Fig. 2). Forty-seven per cent of moose seen on quadrats were within the 14% of the quadrats located on the floodplain and recent burns. The number of moose per quadrat on older burns did not differ from the numbers on forest-muskeg. Quadrats with at least 50% deciduous ground cover had significantly more moose (mean = $2.0 \pm .87$) than quadrats with 45% or less deciduous cover (mean = $0.46 \pm .116$; $t = 3.367$, $p < .01$).

The same pattern of moose distribution was apparent in observations off quadrats. There were significantly more moose than expected on the floodplain and recent burns (Table 5).

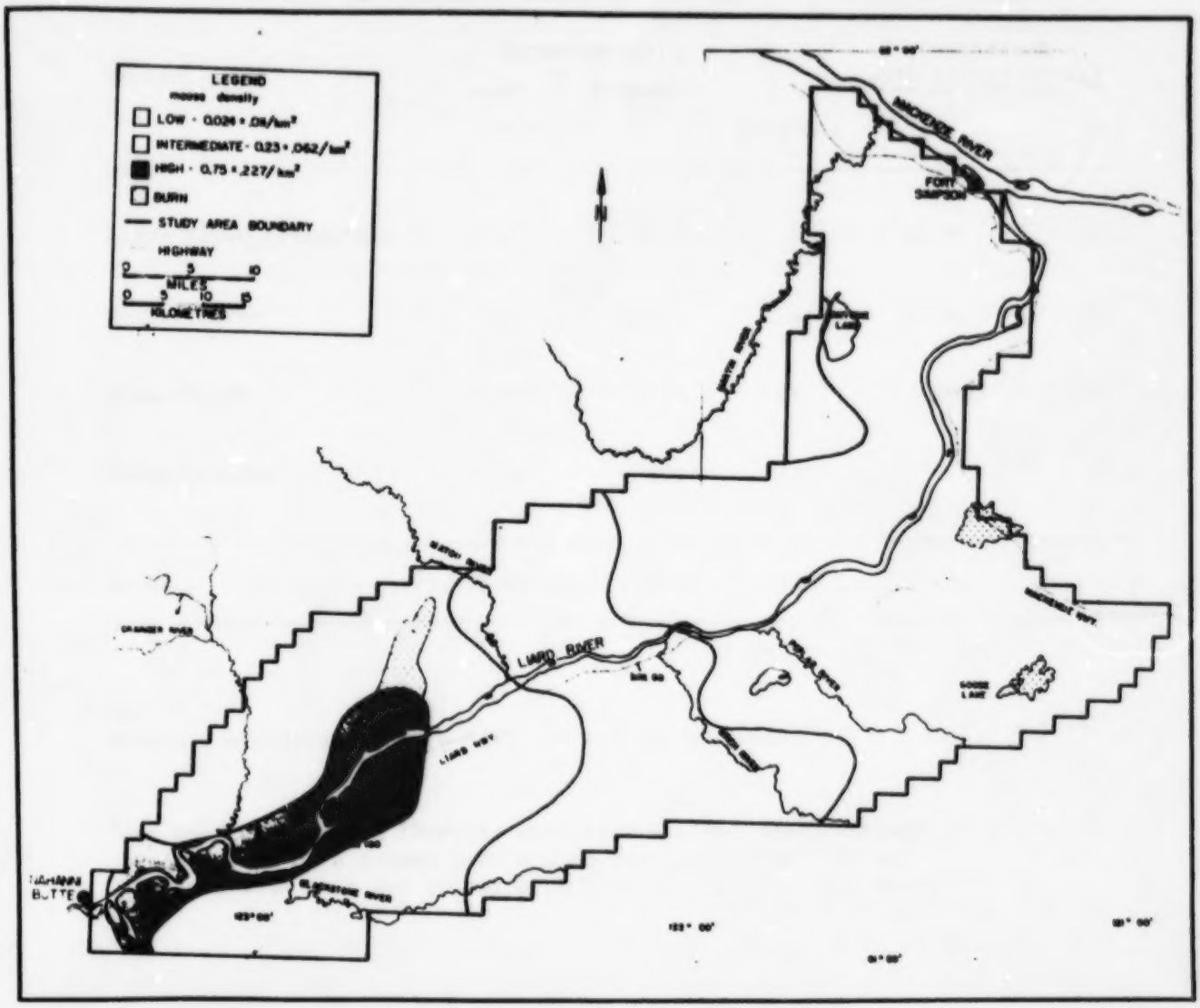

Figure 2. Distribution of Moose.

Table 4. Comparison of moose density in different habitat types in the Liard Valley.

Habitat type	Moose/quadrat mean ± standard error		Quadrats	Comparison with forest-muskeg F	p
Liard River floodplain	1.8±	.57[1]	9	9.26	.005
Recent burns	2.5±	2.5	4	10.14	.005
Older burns	0.35±	.170	17	0.0002	.75
Forest-muskeg	0.37±	.107	63		
Total	0.59±	.146	93		

Analysis of variance: $F = 6.17$, $df = 3.89$, $p \leq .001$.

[1]One quadrat on which 10 moose were seen was excluded. It was located both on a recent burn and on the floodplain. It was included with only the recent burn habitat type for this analysis.

Table 5. Distribution of moose seen off quadrats in the Liard River study area.

	Area (km^2)	Proportion of study area	Expected number of moose	Number of moose seen
Floodplain[1]	230	.04	2.420	18
Recent burn	121	.02	1.273	16
Forest-muskeg	5161	.94	54.307	24
Total	5512	1.00	54.307	58

Test of goodness of fit, $X^2 = 287.6$, $p << .001$.

[1]Eight moose seen on recent burn on the Liard floodplain were included in the recent burn habitat type only.

Fifty-nine per cent of the moose seen off quadrats were on the 6% of the area occupied by the floodplain and recent burns. Group size on the floodplain and recent burn did not differ from the rest of the study area ($t = 1.023$, $df = 71$, $p > .20$).

Moose density was extremely low in areas near roads. We saw only one moose on the 15 quadrats (60 km^2) within 10 km of the Mackenzie Highway. Stratum 1a is adjacent to the town of Fort Simpson. The stratum is accessible from the Mackenzie Highway, the Wrigley Highway, and the section of the Liard Highway constructed in 1970. The virtual absence of moose from this area cannot be explained by poor habitat quality alone. In the Redknife Hills study area 40 km away, deciduous growth represents only an estimated 1% of the ground cover. Yet moose density there ($0.078 \pm .0284/km^2$) was significantly higher than in Stratum 1a ($0.014 \pm .0091/km^2$); $t = 2.157$, $p < .05$).

The pattern is the same on the burns adjacent to and far from the highway. On the burn north of Dehdjida Island (Fig. 1), we saw 10 moose on four surveyed quadrats and 16 moose off quadrats. We saw no moose on either burn by the highway. Only part of one quadrat was on a burn near the highway. However, observations made off quadrats were generally consistent with those on surveyed quadrats.

Hunter Kill

The study area is hunted primarily by residents of Fort Simpson (estimated population size 1000) and Nahanni Butte (population 86). In 1978, Nahanni Butte hunters killed 25 to 30 moose (S. Cooper, National Parks, pers. comm.). In Fort Simpson, hunter kill appears to range from 50 to 65 moose per year. A house to house survey indicated that hunters killed 50 moose in 1977 (Decker and Mackenzie 1979). General Hunting Licence holders reported killing 64 moose between July 1975 and June 1976, and 56 moose between July 1974 and June 1975. It is not known how many of these kills were within the study area.

Other Wildlife

Woodland Caribou

Caribou density is very low in the study area. No caribou were seen on the 93 quadrats. One group of two cows and two calves was seen 8 km southwest of Antoine Lake. Another group of four was seen on the Grainger River system about 7 km outside the study area. Feeding craters were evident on several quadrats. Although moose occasionally dig craters, we assumed that these were caribou craters because they were always associated with large numbers of tracks. The apparently low caribou density is consistent with the observations of the 1978 survey. Decker and Mackenzie (1979) saw only five caribou.

Two bush pilots, M. Patterson of Simpson Air and T. Garrick of Wolverine Air, and B. Cazon, the head of the local Hunters' and Trappers' Association, reported (pers. comm.) caribou wintering in two areas. One area was northwest of the study area and east of the Nahanni Range. The other was southeast of the study area and near Trout Lake.

This is consistent both with information provided by the Land Use Information Series map 96G produced by the federal Department of the Environment[1] and with observations in the transect survey block east of Trout Lake and west of the Redknife Hills where caribou density was estimated at $0.09 \pm .041/km^2$ in February 1979.

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[1]Available from Canada Map Office, Surveys and Mapping Branch, Department of Energy, Mines and Resources, Ottawa, Ontario, Canada K1A 0E9.

Wolves

We concluded that at least one and possibly two wolf packs occupy the study area. Wolves were observed only twice during 70 hours of flying. On January 28, we saw a single wolf 10 km southwest of Fort Simpson. It was black with a white patch on the throat. We recognized it again the next day in a group with two other black wolves. In his 1978 survey of moose in the Liard Valley, Decker (pers. comm.) saw wolves twice in this vicinity, but nowhere else in his study area. L. Dvorak, a pilot with Wolverine Air (pers. comm.), reported seeing wolves twice during the winter. In December he saw a pack of 10 on the burn near Dehdjida Island. Three were black, one was white and six were grey. In March we found a recently killed moose in the same area. Dvorak also saw a single wolf near Nahanni Butte.

Whether the three black wolves seen near Fort Simpson were the same as those of the pack 93 km to the southwest is unclear. Territory size of wolves depends on prey density (Haber, Walters, and Cowan 1976). The predicted territory size for a prey biomass of 280 lb/mi^2 (.347 moose/km^2 x 800 lb) or 50 kg/km^2 is 2680 km^2 (1035 mi^2). Therefore, according to the model of Haber et al. (1976), the 5512 km^2 study area should probably support two packs.

Black Bears

Black bears use the islands in the Liard River as den sites. In September 1978, Sam Miller (pers. comm.) of the Northwest Territories Wildlife Service checked three islands for signs of denning. On Dehdjida Island he found five dens. On the next two islands downriver, he found six and two dens respectively. The majority of dens appeared to have been used the previous winter.

Black bears are an economically important species to the residents of the Liard Valley. From 1972-1973 to 1976-1977 Fort Simpson hunters reported killing 254 bears.

DISCUSSION

Moose Population Status

The recruitment rate for the Liard Valley moose population was 13% calves in February. Recruitment varies greatly among populations and 13% is low to average. Peterson (1955) found that yearlings averaged 15 to 17% of yearling and older moose in populations across North America. In an increasing population in Alaska, Gasaway, Haggstrom, and Burris (1977) found 39 to 44 calves/100 cows in fall and 26 to 35 yearlings/100 cows in spring. While the same population was declining, they found 14 to 30 calves/100 cows in fall and 8 to 21 yearlings/100 in spring. Like the Liard Valley moose, the Alaska population was subject to both wolf predation and hunting. If mortality is similar in the two populations, 13.3% calves or 30.7 calves/100 cows (assuming an equal sex ratio) in winter, likely indicates a stable population.

The sustainable harvest of the moose population depends in part on the level of wolf predation. The wolf population of the Liard Valley may have increased in recent years. There was a bounty on wolves in the Northwest Territories until 1974-1975. The number of wolves reported killed by Nahanni Butte and Fort Simpson residents between 1969-1970 and 1974-1975 ranged from 11 to 38 with a mean of 20.8 wolves/year. In the 2 years following removal of the bounty, fur records indicate that only three wolves were killed (NWT Wildlife Service unpublished records). Removing wolf control may have allowed an increase in wolf numbers.

The sustainable harvest should be well below the estimated 13% calves. Calf mortality should exceed adult mortality until fall, so that actual recruitment will be less than 13%. As well, wolf predation and other non-compensatory mortality could reduce the sustainable harvest below the recruitment rate. The model of Harber et al. (1976) suggests a maximum sustainable harvest may be in the order of 4 to 8% in moose populations exploited by wolves. Applying a 6% harvest rate to the estimated population

size of 720 yields 43 moose/year. This is equivalent to about half of the total reported harvest by native residents of Fort Simpson and Nahanni Butte who conduct part of their hunting in the study area. This crude estimation indicates that hunter kill may be near the maximum sustainable harvest for the lower Liard Valley. Its value lies only in pointing out the management need for more information on moose population parameters, particularly on hunter kill per unit area.

Moose Distribution and Habitat Quality

The areas of greatest moose density during January to March 1979 were the same as those reported by previous winter surveys. Synergy (1975) found moose concentrated on the islands and shores of the Liard River. Decker and Mackenzie (1979) recorded the greatest density on the burn near Dehdjida Island. Both areas represent typical winter habitat of moose. While moose may utilize aquatic vegetation in the summer, during the rest of the year they rely on browse (Peek et al. 1976). The three main sources of available browse are:

(1) riparian willow thickets maintained by annual flooding,

(2) wetland shrub communities maintained by high water levels and poor drainage, and

(3) early successional stages that follow fires.

The riparian fringe of willows and other shrubs is the earliest of three successional stages that occupy the floodplains of the Liard and its tributaries. Willows are the first colonizers of sand bars (Rostad, White and Acton 1976) and the most important browse species in the area (Walton-Rankin 1977). This shrub complex is a stable disclimax maintained by periodic flooding, ice scouring, and sedimentation. It is prime habitat for beaver as well as moose. On higher and better drained parts of the floodplain, balsam poplar is the dominant successional species. Above the average annual flood height, the alluvial soil supports the white spruce edaphic climax.

Fires are more effective than flooding in producing large areas of moose habitat. Following burning, habitat quality usually improves. Moose numbers increase (Peterson 1955, Bishop and Rausch 1974, Krefting 1974, Irwin 1975, Peek et al. 1976, Kelsall, Telfer and Wright 1977, USDA Forest Service 1977, Eastman 1978) through immigration, breeding at younger ages, and increasing the frequency of twins (Pimlott 1959, Markgren 1974). Browse abundance increases for several years. Depending on the areas, it may peak between 11 and 30 years and decline after 20 to 35 years following burning or clearing (Eastman 1974, Stelfox 1974, Kelsall et al. 1977, Oldemeyer, Franzmann, Brundage, Arneson and Flynn 1977).

Fire suppression is a recent practice designed for the protection of property, forestry, and aesthetic values. In the past, Slavey Indians of the Liard and Mackenzie Valleys were fire managers, creating or improving wildlife habitat by burning (Lewis 1978). In the Northwest Territories, fire suppression is the responsibility of the Northwest Lands and Forest Service, federal Department of Indian and Northern Affairs. They use a 4-zone system to determine intensity of fire control effort. Most of the Liard Valley belongs to zone 2 with zone 1 areas around settlements. All fires are suppressed in zone 1 and, except under the most abnormal burning conditions, in zone 2 (Anon. 1974). Thus the current policy is to suppress all fires in the Liard Valley.

The fire control policy is not conducive to maintaining or improving moose habitat. Unless land is burned or cleared, moose will continue to be concentrated in the alluvial flats with a very low density throughout the rest of the Liard Valley.

Impact of Highway Construction

There are several potential impacts of highway construction on moose and other wildlife populations. As well as the direct effects of:

(1) construction of the highway,

(2) activity during construction, and

(3) the presence of a highway and traffic after construction,

there are secondary effects arising from the access the road provides. The most immediate effect is hunter access to the area. The incidence of fires also may increase and forestry and/or agriculture may become established.

Construction and Traffic

Disposal of slash, changes in drainage patterns, and removal of granular deposits may affect moose movements and habitat. During clearing operations, unburned slash should be left as discrete piles rather than in long rows. Unbroken rows of slash will act as barriers to moose (Usher 1977) and may fence them on to the highway. Drainage patterns should not be disturbed. If the highway diverts water away from a wetland shrub community maintained by high water levels, succession will resume. Good moose habitat will be succeeded by a forest community with low browse production. The alluvial flats on the Liard and its tributaries that produce excellent winter range also provide good sources of gravel and other granular deposits (Rostad et al. 1976). Removal of these deposits on the edge of rivers will cause the loss of valuable permanent habitat.

Activity around camps and construction sites may cause some problems. Initially wildlife may avoid these area. For example, in Wyoming, elk maintain a minimum distance from area of ongoing logging activity, but resume use of the area when human activity has ceased (Ward 1976). In

unhunted wildlife populations in parks, animals may become habituated to human activity (Johnson and Todd 1977, Schultz and Bailey 1978). However, habituation of some species presents problems. To avoid problems with bears, wolverines, foxes and wolves, garbage should be burned daily in an incinerator. Warnings against feeding wild mammals should be displayed and laws should be enforced.

Recreational activities of construction workers present potential dangers to wildlife. Legal and illegal hunting can overharvest wildlife populations. Construction workers should be prohibited from hunting. In northern British Columbia in this decade, poaching by railway construction workers caused goat populations to decline along parts of the British Columbia Railway route (D. Hatler, British Columbia Fish and Wildlife Branch, pers. comm.). In the past men in coastal logging camps often hunted grizzly bears. One logger killed over 100 bears in 10 years (B. Smith, Yukon Game Branch, pers. comm.). Snowmobiles are also a serious threat to wildlife. Chasing moose and caribou in late winter when fat reserves are depleted can kill them.

The highway may become a travel route for moose, caribou, and wolves. In Sweden, reindeer use roads for winter travel (Klein 1971). Barren-ground caribou preferentially use seismic lines over adjacent forest during migration (Banfield 1974). Wolves hunt these same seismic lines.

The major problem with ungulate use of highways is collisions with vehicles. On a 92 km stretch of highway around Burns Lake, British Columbia, 0.22 moose/km were killed annually from 1973-1974 to 1976-1977 (20/year) (British Columbia Fish and Wildlife Branch, unpublished data). An additional 0.20 moose/km/year were killed on the railway adjacent to the highway from 1973-1974 to 1975-1976 (18/year). On another British Columbia railway, 0.45 moose/km were killed in the winter of 1973-1974 (56 moose in 122 km). In northeastern British Columbia, an estimated 300 moose and other ungulates are killed each year. In the Yukon the estimate is 50 to 100/year (Beak Consultants 1979).

The number of moose killed in collisions with vehicles may exceed a sustainable harvest. For example, along 189 km of the Laurentides Highway in Quebec, 0.18 moose/km were killed annually from 1966 to 1972 (35 moose/year) (Grenier 1973). This represents 15 to 20% of this population which would be more than a sustainable harvest for populations subject to wolf predation.

The seasonal distribution of accidents differs among areas. It likely depends on traffic patterns, snowfall, maintenance practices and possibly, day length. Most accidents occur at night (Grenier 1973). On the Liard Highway, fall and winter may be most critical. Days are short and as snow accumulates, moose may use the cleared road for travelling.

Besides contributing to moose mortality, collisions result in property damage and human inconvenience, injury and death. Several preventative measures are possible. Leaving wide rights-of-way may make moose and vehicles more visible. Snowplows should maintain low snowbanks to facilitate movement off roads. Salting should be avoided as it attracts ungulates to roads in summer (Grenier 1973). Reducing speed limits at night and from October to February in prime habitat (deciduous growth on alluvial flats and burns) should reduce accidents. Warning signs in these areas may increase driver awareness.

Recreational sites should be constructed with certain considerations. They should avoid areas frequented by moose cows and calves from May to July; and areas of high bear density such as the islands in the Liard River.

Hunter Access

The greatest impact of the Liard Highway will probably come, not from its construction, but from the access it provides. Hunter effort along the highway corridor will likely increase. In northern Alberta, 80% of hunter effort and 23% of total kill is within 1.6 km of a road (Lynch 1973). In

a Newfoundland study, the mean distance travelled from a road to shoot a moose was 0.58 km in 1960 and 0.92 km in 1961 (Bergerud, Manuel and Whalen 1968). Although most Liard Valley hunters currently use boats or snowmobiles (Decker and Mackenzie 1979), road hunting may increase once the Liard Highway is constructed. The road may also attract hunters from elsewhere in the Northwest Territories.

A British Columbia study (Murray 1974) found that constructing roads into ranges of previously inaccessible moose populations consistently resulted in overhunting and a decline in population size. Populations subject to wolf predation are particularly sensitive to overhunting (Haber et al. 1976). In Alaska, severe weather and intensive hunting drove a moose population to a level where wolf predation became its primary limiting factor (Gasaway et al. 1977). Curtailing hunting was not sufficient to allow an increase in numbers. Wolf control had to be implemented before moose recruitment and numbers increased.

The lower Liard Valley may be sensitive to any increased hunting pressure. The extremely low density of moose in Stratum 1a likely results, in part, from its proximity to Fort Simpson hunters and its accessibility by road. The sustainable harvest in the Liard Valley is not likely to increase without major increases in habitat quality. The current trend is toward late and unproductive successional stages. Also, wolf numbers may be increasing. Both these factors tend to reduce recruitment, and hence the sustainable harvest. If hunting pressure is already near the maximum sustainable level, increased harvest can cause a decline in moose numbers.

Certain measures can minimize the increase in harvest. First, hunting ungulates, bears and beavers should be prohibited within 5 km of either side of the highway. Second, construction of side roads should be limited. Especially critical areas are the alluvial flats along major rivers. These support prime permanent moose habitat. Third, access to side roads should be restricted. Roads no longer required should be made inaccessible to hunters.

Forestry and Agriculture

Construction of the Liard Highway will provide access for the development of forestry and agriculture in the area. The Liard Valley supports some of the best timber in the Northwest Territories (Rostad et al. 1976, Hirvonen 1968). Most of the good timber is south of Fort Liard; some stands occur between Fort Liard and the Blackstone River within 10 km of the Liard. Little commercial timber is found northeast of the Blackstone (Rostad et al. 1976). The most valuable stands are white spruce on the higher alluvial floodplains (Rostad et al. 1976). During the summer of 1979, the Northwest Lands and Forest Service plans to conduct an inventory of the Liard Valley. After completion of the inventory, cutting permits may be issued.

Logging operations can have an effect similar to fire on moose habitat: mature forest reverts to early successional stages. As after fires, browse production is low initially, increases for a number of years, and declines as the forest matures past 20 to 35 years. Logging differs from burning in two major respects. First, the size and shape of the cutover area can be controlled. Second, logging brings roads, human activity, and hunters into the area.

The current forestry practice in the Northwest Territories is selective logging (W. Mawdsley, Northwest Lands and Forest Service, pers. comm.). Selectively cut areas will not increase available browse if the forest canopy is not reduced sufficiently to allow successional growth (Peterson 1955). More extensive selective cutting produces optimal habitat. In an area of high snowfall in British Columbia, Eastman (1974) found that moose preferred partially logged stands as winter habitat over clearcut areas.

Moose do not use very large clearcut or burned areas (Peterson 1955) as they tend to remain close to cover. Telfer (1974) suggests moose may use clearcuts up to 1.3 km^2 in area, inferring that moose will move up to 0.6 km into open areas. However, Hamilton and Drysdale (1975) found that moose infrequently went more than 40 m from cover and never beyond 100 m. The distance moose tend to move likely depends on browse abundance, hunting pressure, and snow depth. In the Liard Valley, snowfall should not be sufficient to confine moose to cover. The distance to cover can be minimized (and availability of good winter range maximized) by:

(1) clearcutting small areas,

(2) clearcutting forest in long strips (up to 200 m wide) perpendicular to the prevailing winter winds, and

(3) leaving patches of undisturbed habitat within large clearcuts.

These practices should also benefit other species, especially marten. Marten are the most vulnerable species to logging as it removes cover, food sources and den sites for this commercially valuable fur-bearer. During winter, marten confine their hunting activities to forested areas (Koehler and Hornocker 1977) where their food source is primarily microtines. A thick layer of snow in open habitats prevents access to microtine prey living in the subnivean layer (R. Archibald, Yukon Game Branch, pers. comm.). Once a portion of the forest has been clearcut, it will no longer support a resident marten population. Selective logging that creates a mosaic of forest and small openings should not be detrimental to the marten population. It is important that shrubs and some slash be left in the clearcut areas. This will enhance settlement of an area by voles and other microtines, will increase berry and insect production which are auxilliary summer food sources for marten, and will leave cover for hunting. Selective logging also leaves trees available for den sites.

While forestry can improve moose habitat, it also creates problems. Logging roads will provide access for hunters, activity may disturb wildlife, and trucks may collide with moose. To prevent overharvesting of moose:

(1) logging roads should avoid the willow-shrub complex on alluvial flats, and

(2) use of logging roads should be strictly controlled.

The same precautions recommended for construction camps and highway traffic apply to logging camps and roads.

Rostad et al. (1976) reviewed the agricultural capabilities of the soils of the Liard Valley. They proposed that one-third of the land (1,000,000 acres or 405,000 hectares) can support some type of agriculture. The native vegetation cannot support livestock. Both ranching and farming would necessitate clearing, fertilizing, seeding and, possibly, draining land. The most arable sites are on the alluvial floodplains.

As well as having the greatest agricultural potential, the alluvial flats produce good moose and beaver habitat on the lower sites and commercial stands of white spruce on higher ground. Clearing land for agriculture would destroy prime winter habitat for moose. Draining would destroy the ponds and waterways required by beaver and muskrat (Ondatra zibethicus).

The floodplains can be used productively for several purposes: hunting, trapping, forestry, agriculture, roads, borrow pits, and construction sites. Reserving these areas for hunting and trapping would be most compatible with the life-style of the native residents of the Liard Valley. If the floodplains are developed, logging of white spruce would have the least disruptive effect on wildlife habitat. The impact could be minimized by:

(1) leaving the riparian fringe of deciduous trees and shrubs intact,

(2) leaving riverbanks and the floodplains on small streams undisturbed to prevent slumping or erosion, and

(3) using culverts and bridges in road construction to maintain the current pattern of water drainage.

SUMMARY OF RECOMMENDATIONS TO MINIMIZE IMPACT

Habitat

1. The willow-shrub complex on the edge of floodplains is prime winter habitat. Disturbances of this fringe by roads, borrow pits, camps, and farms should be avoided. The least disruptive use of these areas, aside from controlled hunting and trapping, is forestry on the higher alluvial sites.

2. Drainage patterns should be maintained using culverts or bridges.

3. Generally, fires should not be controlled. Prescribed burning of small areas should be considered where:
   (a) the site will regenerate to good moose habitat, and
   (b) the timber has little commercial value.

4. Logging operations should use:
   (a) small or linear clearcuts, or
   (b) larger clearcuts with patches of habitat left undisturbed for moose cover and hunting and denning sites for marten.

Roads

1. Granular deposits needed for construction should be taken from alluvial sites above the flood zone where the forest cover is white spruce.

2. Long slash piles and high snowbanks should not be left adjacent to the highway. They may fence wildlife on to the road and increase the probability of vehicle-wildlife collisions.

3. Wide rights-of-way adjacent to the highway would increase visibility and reduce vehicle-wildlife collisions.

4. Roads should not be salted.

5. Side roads, boat launching ramps, and other constructions should avoid the willow-shrub complex on alluvial flats and bear denning areas.

6. Construction of, and access to side roads should be limited.

Human Activity

1. In camps, garbage should be burned in an incinerator and buried daily. Laws against feeding animals and chasing them with snowmobiles should be strictly enforced.

2. Picnic and camping sites should not be constructed in:
   (a) areas of moose cow-calf concentrations, or
   (b) areas intensively used by bears for denning or feeding.

3. Low speed limits in prime habitat in fall and winter and warning signs may reduce vehicle-wildlife collisions.

Hunting

1. Construction workers and loggers should be prohibited from hunting.

2. Hunting ungulates, bears and beavers should be prohibited within 5 km of either side of the highway.

3. A management plan should be constructed to prevent overharvest of moose.

RECOMMENDATIONS FOR FURTHER RESEARCH

1. Surveys to estimate density and recruitment of moose should extend along the highway corridor from the Mackenzie Highway to the British Columbia border. Late November and early December may be the best time to estimate numbers (Lynch 1975). Moose tend to use more open habitat than later in the winter, and there is enough snow to make them conspicuous. Reconnaissance flights should first delineate moose distribution in order to stratify and optimally allocate survey effort. If distribution is generally similar to the late January to early March period, then two strata should be used: (a) the island and shores of the Liard River, and (b) the rest of the highway corridor. Optimal allocation of effort (Cochrane 1977) will likely allow 100% coverage of the floodplain.

2. An investigation of inventory techniques may increase accuracy and precision of surveys of a given cost. In 1979 two methods were used to survey moose in the Northwest Territories, both using fixed-wing aircraft. The quadrat survey method used in this study apparently suffered little observer bias. However, surveying quadrats is time-consuming and therefore costly compared to transects. Consequently coverage is low, variance is high, and estimates are imprecise. Conversely, transect surveys can yield more precise estimates (lower variance) because coverage can be greater for a given cost. But they are less accurate because some moose are not detected. Any review of inventory procedures should consider shape of sampling units, flight pattern, type of aircraft, methods of estimating and/or reducing observer bias, and statistical design and analysis.

3. If censuses are conducted in the fall, recruitment should still be estimated in March. Aerial segregations are easier from a helicopter than a fixed-wing aircraft. In one British Columbia region, the Fish and Wildlife Branch found it economical to use a fixed-wing aircraft

to locate moose and to communicate their location to a helicopter crew who then classified them (D. Lowe, pers. comm.). The cost saving from the reduced searching time by helicopter more than compensated for the additional cost of the second aircraft.

4. Currently, the most pressing management need is for accurate information on the size and location of the moose harvest. Eventually, estimates of the rate of wolf predation may be needed.

5. Information is needed on areas used by cows during and after calving (late May to early July) in order to minimize disturbance to them.

6. Before specific recommendations on fire control and prescribed burning can be made, more detailed information is needed on which areas will regenerate to good moose habitat.

7. Once highway use begins, information on vehicle-wildlife collisions should be collected, and should include number, location, age and sex, season and time of day.

8. Areas of high marten density should be determined.

9. The islands of the Liard River should be searched for black bear dens.

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